S. MORGAN SMITH CO.
YORK, PA., U. S. A.

SPECIFICATION No. 18369 - 6608

FOR

CITY OF MARTINSVILLE, VA.

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1. GENERAL DESCRIPTION.

This specification is intended to cover the design, construction and testing of.....one.....single runner vertical turbine arranged for direct connection to electric generator :

The turbine gates to be of the wicket type operated through suitable mechanism by a governor located on the generator floor. Governor pumps, tanks and piping for the pressure supply system will be located and adapted, so far as possible, to suit the design of the power house.

The turbine shaft will be supported by.....one.....bearing of the...lignum-vitae...type mounted on the crown plate and arranged for.....water.....circulation.

The turbine casing will be..of...cast...iron...and...constructed...for...installation in...an...open...concrete...flume.

The gate mechanism will be operated by...a...torsional...gate...shaft...governor..... located...on...the...generator...floor.

All moving parts of the gate mechanism will be fitted with renewable bronze bushings except the gate shaft bearings which bearings will be lined with babbitt, thoroughly peened and accurately bored. All the gate mechanism will be accessible for adjustment and repair after the water is drained from the flume.

The weight of the rotating parts of the turbine and the hydraulic thrust on top of the runner are to be carried by a thrust bearing on top of the generator which thrust bearing is not included herein.

This specification covers.....one.....complete turbine with governor system and all necessary auxiliar...ies.....herein expressly stipulated.

5. RUNNER.

The runner ~~xxxx~~ blades will be annealed steel castings with trunions cast integrally.

It will be machined on the outside for close running fit with the curb ~~xxx crown~~ plate~~x~~ The vanes will be carefully rounded and worked down to a smooth surface and the runner will be accurately balanced after all other work is completed.

~~If the shape of the runner permits, allowance will be made for a small vertical clearance above or finished ledge or shoulder on the casting at the top of the draft tube, which ledge serves to support the runner when it is disconnected from the shaft. The runner is designed to support the weight of the turbine shaft but not the generator shaft or rotor.~~

The hub will be an annealed steel casting made in one piece and will be provided with bronze bushed bearings for the blade trunions.

The blades are operated by a rod extending thru the shaft and attached to a cross-head with link connections to the cranks on the blade trunions.

The hub will be faced and drilled to receive the main shaft.

6. GATES.

The turbine gates will be of the wicket type made of cast iron mounted on steel stems extending thru the top plate. They will be machined on the top and bottom to gauges and on the contact surfaces to templates thus making them interchangeable. All parts of each gate not machine finished will be carefully hand dressed to reduce frictional resistance to a minimum.

7. CURB AND CROWN PLATES.

The crown plate will be of cast iron in one piece, of heavy construction and substantially ribbed. It will be cast integral with the speed ring. The crown plate will be fitted with bronze bushed bearings through which the gate spindles extend.

~~The crown plate will be carefully bored to establish the proper clearance with the outside of the runner crown.~~

The water face surface will be machine finished all over and will have a raised annular boss located to match the point of contact between the gates when in their closed position. This arrangement reduces the gate leakage to a minimum and at the same time provides a free clearance with the ends of the gates when open. The same arrangement is used on the water face surface of the curb plate.

The crown plate is designed to support the main shaft bearing.

The curb plate will be of cast iron in one piece~~s~~ and will be ~~bolted to the~~ cast integral with the speed ring. It will have bushed bearings for the lower ends of the gate spindles.

The curb plate will be carefully finished wherever necessary.

The curb plate extension or the runner barrel will be made of rolled steel and reinforced with ribs machined, bored and faced for attachment to the speed ring.

8. SHIFTING RING

The shifting ring will be of cast iron in halves to facilitate erection and dismantling. It will be machine finished where it rides on the bearing surface of the crown plate and will have machine finished lugs to which the bolts connecting it with the gate operating links are attached. It will also have two heavy lugs properly machine finished to permit of attaching thereto the operating rods between it and the gate shaft.

2. PROPOSAL DRAWINGS.

The following drawing and photographs accompany and form part of these specifications:

P-1063-S-1 - Showing elevation and plan of unit.

Photographs Nos. 1716 and 1717 showing construction of similar turbine.

In case of discrepancy between...this.....drawing and the following specifications, the latter shall take precedence.

3. CAPACITY AND EFFICIENCY.

The turbine.....is.....guaranteed when operating at a speed of.....300.....R. P. M. to give not less than the following power and efficiency:

The guaranteed performance of this turbine is shown on curve sheet dated May 4, 1931 and attached to this proposal.

~~Data Sheet dated ..... shows curves applicable to this installation plotted from test of a model runner of homologous design.~~

4. TESTS.

The performance or non-performance of the guarantees herein specified shall be determined by testing one or more turbines, to be selected jointly by the Company and the Purchaser. Such test or tests shall be made in accordance with the Standard Code for Testing Hydraulic Turbines adopted..... October 1917.....by the....Machinery Builders Society..

The output of the turbine shall be measured in accordance with Article.....of said Code.

The quantity of water used shall be measured in accordance with Article.....of said Code.

The head acting on the turbine shall be measured in accordance with Article.....of said Code.

Any of the applicable methods described in said code.

9. MAIN BEARING.

The main shaft bearing will be bored 7-1/2 in. diameter and consist of a cast iron housing made in halves and bolted to the crown plate. It will be of the Magnus-Vitae type and arranged for water circulation.

10. PIT LINER. NONE REQUIRED.

The pit liner will be of cylindrical form and will be made of..... It will extend to a height of.....ft. above the center line of the distributor and will be bolted to..... .....

11. SHAFT.

The shaft will be of forged open hearth carbon steel. It will be 7-7/16 in. diameter at the coupling end extending 24 ft. 0 in. above the center line of turbine distributor to the face of a forged flange for connection to the generator shaft. This flange will be finished to template and gauges furnished by the Purchaser or generator manufacturer. The bolt holes will be bored 1/32 in. small and shall be reamed to size after assembling in the field. The reamer for this purpose, together with the coupling bolts will be supplied by the Company.

The shaft will be furnished in two pieces. The extension shaft will be enlarged at its upper end and machined to accommodate the servo motor piston.

The shaft shall be hollow throughout its entire length and contain the draw rod which actuates the runner blade adjusting device.

12. GATE SHAFTING AND BEARING.

The gate shaft will be of forged carbon steel made in two pieces 6-7/16 in. diameter. This shaft will be of the proper length to connect with the operating lever of the governor and with the rocker arm of the turbine. If this shafting is in two pieces and one piece offset from the other as is sometimes necessary in case of steel pressure flume settings being used, the necessary interconnecting levers and links will be supplied by the Company.

All bearings to support gate shafting will be of cast iron with babbitt lining, thoroughly peened and accurately bored. All necessary anchor bolts for gate shaft bearings will be supplied by the Company.

Two of these bearings shall be located in the flume and the third shall be formed as a part of the governor base.

13. GATE OPERATING MECHANISM.

Each gate.....is connected to the shifting ring by means of a cast iron link, two steel bolts....and a lever..... The bolts at one end of each link are eccentric and thereby provide independent and accurate adjustment of each gate in the closed position. The links will be designed to be the weakest element in the gate mechanism.

The shifting ring is connected at opposite points through steel connecting rods to a rocker arm on the gate shaft, therefore, any movement of the gate shaft is transmitted to the gates through the connections described above.

All working joints and pin connections throughout the gate mechanism will be provided with renewable bronze bushings.

14. DRAFT TUBE.

The draft tube will be made of.....plate steel.....in accordance with that Article specifically applying thereto.

Concrete.—Concrete draft tube (if specified) shall be formed in the concrete substructure of the power house according to drawings furnished by the Company. The Company's construction drawings shall show the shape of the water passages only and all other details of construction shall be determined by the Purchaser. All expense of construction shall be borne by the Purchaser and the Purchaser shall be responsible for strength and suitability of the substructure and durability of the draft tube. No limitations shall be imposed by the Purchaser upon the Company's design other than to maintain a clear width of water passage at discharge end of draft tube of.....ft.....in. and a distance from center line of turbine distributor to bottom of tailrace of.....ft.....in. The center line distance of unit will be.....ft.....in., maximum allowable draft head.....ft.....in.

Plate Steel Type.—If such material is specified, the draft tube will be made of rolled steel plates .....5/16....in. thick.

If of the vertical type, it will be.....5.....ft.....0.....in. diameter at the small end and .....8.....ft.....0.....in. at the outlet end and will extend to a depth of...13.....ft.....0.....in. below the center line of the distributor.

If its dimensions are within allowable shipping limits, it will be shipped riveted up in.....one..... ~~telescoped~~ sections. In case its dimensions exceed allowable shipping limits, it will be rolled, punched, assembled and match marked and shipped knocked down.

All necessary field rivets will be supplied by the Company.

Adjustable tie rods for bracing the draft tube to the side walls will be furnished.

15. DRAFT TUBE FLANGE.

The flange at the top of the draft tube will be of ~~cast iron~~ rolled steel in.....one.....piece , faced and tapped to receive the lower flange of the..... It will have drilled holes to permit of riveting the plate steel draft tube thereto, in case such a draft tube is used. ~~If the shape of the runner permits, allowance will be made for a small vertical clearance above a finished ledge or shoulder on the inside of this flange, which ledge serves to support the runner when it is disconnected from the shaft. The ledge will be of ample strength to support the weight of the runner and turbine shaft, but not the generator shaft or rotor.~~

16. DRAFT TUBE LINER. NONE REQUIRED.

The upper part of the draft tube will be lined to a point.....ft.....in. below the center line of the distributor. The liner will be of the following construction, viz.:

17. FLUME.

The flume shall be of the rectangular type made of concrete in accordance with that section of this Article applying thereto.

Concrete.—Concrete flume specified at the top (~~if specified~~) shall be built by and at the expense of the Purchaser in accordance with drawings furnished by the Company. The Company shall determine the velocities to be used and shall be restricted in the development of the design only to a clear width of water passage of 15 ft 0 in. at entrance. The Company's construction drawings shall show only the shape and dimensions of the water passage and all other details such as re-inforcing, manholes, etc. shall be designed by the Purchaser. The Company assumes no responsibility for the strength or any detail of construction other than shape and size of the flume.

Unless specifically stated hereinafter, manhole equipment for access to the interior of the flume shall be furnished by the Purchaser.

Plate Steel.—If such a flume is specified, it will be of cylindrical shape.....ft.....in. diameter and made of steel plates.....in. thick. The inlet on the side thereof will be of the same material.....ft.....in. diameter and extend to a point.....ft.....in. from a plane passing through the center line of the flume.

The flume heads will be of cast iron in.....piece of heavy construction and substantially ribbed. They will be properly machine finished where necessary and have drilled holes to permit of riveting the flume shell thereto.

The top flume head will be provided with a heavy cast iron.....cover plate in..... piece large enough to provide ample clearance for removal of largest part of the turbine casing. The flume will be fitted with a large manhole frame and cover, also a suitable drain valve conveniently located.

The top flume head will be provided with adjustable packing boxes for the turbine and gate shafts

18. COVER PLATE FOR GENERATOR WELL.

~~If required,~~ a plate to cover the well or pit opening beneath the generator will be supplied. It will be of plate steel in two pieces of heavy construction and substantially secured to the bottom of the concrete generator well. A curb ring of structural steel on which to bolt the cover plate will also be supplied. ~~The cover plate will be fitted with an adjustable packing box for the wheel shaft and if feasible a manhole cover will also be provided.~~

In connection with this equipment a separate rocking with adjustable packing box for the gate shafts will be supplied.

19. AUXILIARY MAIN SHAFT BEARING.

The auxiliary main shaft bearing will be of the lignum-vitae type bored 7-7/16 in. diameter and consist of a cast iron housing made in halves with machine finished base for bolting to a structural steel support.

Lignum-Vitae.—The cast iron housing will contain four lignum-vitae blocks and steel follower plates. Adjustments for the blocks being provided by means of bronze tramming bolts equipped with bronze lock nuts. End cover plates and base bolts for the bearing housing will be furnished. The housing will have suitable openings for water supply from the flume.

Babbitt Bearing.—This will consist of a cast iron shell made in halves and lined with babbitt, thoroughly peened, bored and grooved for oil circulation. The housing will have a machine finished base for bolting to a suitable support. It will be provided with a dust proof split cover plate.

An oil circulating device suitably supported and driven from the main shaft together with a strainer and necessary piping will be supplied. This device is designed so that oil passing through the bearing is reclaimed.

20. SUPPORTS FOR AUXILIARY MAIN SHAFT BEARINGS.

Supports for the auxiliary main shaft bearing shall be supplied by the company and are included herein.

The structural steel support shall consist of a double 15" channel spanning the flume with a 12" I-beam connecting the channel to the back wall of the flume. The I-beam is to be centrally located. The entire supporting structure shall be mounted on brackets so that it can be conveniently removed and replaced. Anchor bolts for the wall brackets are to be furnished.

21. DRAINS.

The following drains will be supplied; viz.,

One (1) 12" hand operated drainvalve of the bevel seat type with a short lifting stem shall be furnished for installation in the flume floor.

22. BRAKES.

The brakes necessary to stop the unit after the turbine gates have been closed shall be supplied by the generator manufacturer and are not included herein:

23. GOVERNOR.

The turbine will be equipped with a 12,500 foot pound S.K.F. torsional shaft governor located on the generator floor, arranged to operate the gates by means of vertical gate shaft, rocker & two operating rods The governor will be supplied with ..... at ..... lbs. per sq. in. pressure by a pressure system described in Article 24.

The governor will consist of a centrifugal speed element driven by G.E. Co. 110 volt, 3 phase, 60 cycle motor. It will be complete with hand control, load limiting device, gate indicator, synchronizing attachment, also necessary anti-racing mechanism between the gate operating mechanism and governor. A tachometer is not included.

The synchronizing attachment will include a 110 volt D. C. motor with split field together with suitable reversing switch. No wiring is included.

The governor is guaranteed to operate the gates over full range in ..... seconds. It will operate satisfactorily with governors of the same make or with governors which in turn operate properly in parallel with other governors.

When operating under the conditions stated below, the speed regulation for sudden load changes will be as follows:

Normal speed of turbine ..... 300 R. P. M.
Net effective head ..... 30 Feet
Length of pipe line ..... x Feet
Average diameter of pipe line ..... x Feet ..... x Inches
Average velocity in pipe line for x H. P. load on x turbine x Ft. per Sec.
Full gate stroke—Load on 6 Sec., Load Off 2 Sec.
WR Square in generator rotor 66,800 Ft. Square lbs.
Speed Variation.

Sudden Load Change	Load On	Load Off
1350 H.P.	x % Speed Drop	27.0 % Speed Rise
1012 H.P.	x % " "	19.0 % " "
675 H.P.	39.5 % " "	11.6 % " "
337 H.P.	16.0 % " "	5.0 % " "
135 H.P.	5.5 % " "	1.8 % " "

The governor will be sensitive to a speed variation of ¼ of 1 per cent. With constant load and head there will be no hunting and under fluctuating load the gates will not be moved unnecessarily. After any change of load to the extent of full load, the governor will correct the gate opening and adjust the speed to normal in minimum time.

24. GOVERNOR PRESSURE SYSTEM.

The pressure will be supplied by oil at 200 lbs. per sq. in. by a motor driven rotary oil pump. The pump will be of rigid construction and will have sufficient capacity for one unit.

If motor driven, the pump will be driven through a silent chain provided with suitable guard by an A. C. motor wound for 220 volts, 3-phase, 60 cycles. ~~If belt driven, the pump will be driven from a pulley on the main shaft. Necessary pulleys and belt tightener will be furnished. Oil and belts shall be furnished by the Purchaser.~~ The pump will be equipped with an automatic unloading valve to control the pressure limits. G.E. Co.

A sump tank is formed as a part of the pump housing and a plate steel pressure tank will be provided and mounted on top of the pump housing. The pressure tank will be provided with pressure and sight gauges.

All piping, valves and fittings for the governor system will be supplied. The material is based on a center distance of units of.....ft.....in. If this is exceeded or the location or arrangement of governor pressure system is materially altered from that shown on the proposal drawings the additional material will be supplied at an extra charge on a basis of cost plus a profit of.....%. The piping will be standard wrought iron piping and valves will be cast iron body, bronze mounted. All piping will be thoroughly cleaned inside and protected for shipment. It will be shipped in standard lengths to be cut and threaded in the field except such piping that can be fitted to advantage in the shop.

25. FLYWHEEL. NONE REQUIRED.

A flywheel if required shall be supplied by the.....and is.....included herein: if furnished by the Company it will be made of..... and constructed as follows:

26. THRUST BEARING AND SUPPORT FOR ROTATING PARTS OF TURBINE.

The weight of the rotating parts of the turbine and downward hydraulic thrust on the runner, which are calculated to be.....42,000.....pounds, at.....30 ft.....head, shall be carried on a thrust bearing located on top of the generator. No part of this bearing, the support for same, or lubricating system for same are included in this specification.

27. SUPPLY PIPE. NONE REQUIRED.

A supply pipe will be furnished, connecting the entrance of the flume to the..... and extending to a point.....ft.....in. from the longitudinal center line of the turbine.

The supply pipe will be constructed as follows:

28. WEIGHTS.

Estimated weights are as follows:

Heaviest part (.....) – .....pounds.

Total weight of one turbine – – – – – – – – – – – – .....pounds.

29. SPARE PARTS. NONE INCLUDED.

The following spare parts will be supplied:

30. MISCELLANEOUS.

The following additional miscellaneous parts will be supplied:
All necessary lubricating devices.
Necessary packing for all stuffing boxes.

31. TEST OF MATERIAL.

Shop tests of material shall be made if specifically required by the contract. Such tests shall be made by and at the expense of the Company, and in accordance with the standards of the American Society for Testing Materials.

32. RUNAWAY SPEED.

The estimated maximum speed of the turbine with no load at...30.....ft. head is....600.....R. P. M.

33. DIRECTION OF ROTATION.

The turbine will be designed for.....clockwise.....rotation.

34. SHOP ERECTION.

The turbine will be assembled in the shop and match-marked and doweled to insure correct assembly and alignment in the field.

35. PAINTING.

All unfinished surfaces exposed to water will be given two shop coats of red lead and oil, other surfaces will be given a shop coat of graphite paint, except surfaces to be covered with concrete in the field,..... ..... All finished surfaces will be coated with slushing grease before shipment.

All painting after erection shall be done by the Purchaser.

36. PACKING FOR SHIPMENT.

All apparatus sold for export or for transportation by water will be boxed or packed in accordance with the customary requirements.

Domestic shipments in carload lots will not be boxed or crated except small parts such as bolts and fittings, gauges, or delicate apparatus such as governors. Heavier parts will be securely blocked in position on cars. Finished surfaces liable to injury in handling will be protected by lagging or other suitable means.

All special provisions such as skids and cradles for transportation by wagon or otherwise from railroad to power house, unloading by hand, etc., will be provided only upon specific instructions from the Purchaser and at an extra charge.

37. CONSTRUCTION DRAWINGS.

The Company will furnish promptly outline drawings of the foundations required for setting the machinery herein specified, together with similar drawings of the draft tube and flume.

Assembly drawings of the turbine showing the arrangement of all principal parts and drawings of the governor system showing arrangement of piping, etc., will also be supplied.

Drawings submitted with the proposal are preliminary and are not to be used for construction.

38. FOUNDATIONS.

All foundations for the apparatus herein specified shall be furnished by the Purchaser. In so far as they may be affected by the design of said apparatus, they shall conform to the Company's drawings. All reinforcing for the concrete, structural steel supports, stairways, pit-ladders floor plates and railings (unless herein specifically named), shall be furnished by the Purchaser.

S. MORGAN SMITH COMPANY,

By .....

Dated

May 11, 1931.

AY/HM

SPECIFICATION NO. 15369-A.

1. GENERAL DESCRIPTION.

This specification is intended to describe the new parts to be furnished to adapt the single runner horizontal wicket gate turbine shown on our drawing No. 1063-C to its new location in the new powerhouse adjacent to the vertical shaft turbine shown on our drawing P-1063-J-1.

2. DRAFT TUBE.

The draft tube will be made of 5/16" rolled steel plates. It will be of the vertical type and of proper design at the top to fit the flange under the discharge elbow. It will be flared to a larger diameter at the discharge end and will be of sufficient length for proper submergance under the tail water level. Three adjustable stay rods will be furnished for anchoring the draft tube to the side walls of the tail pit.

3. INLET PENSTOCK.

One inlet pipe connecting the present steel pressure flume to the forebay will be furnished. It will be 15'-6" long measured on

the centerline, 6'-6" diameter where it joins the pressure flume and 9'-6" x 7'-0" where it is anchored in the concrete at the entrance to the forebay. The penstock will contain a transition section changing the rectangular section at the forebay to a circular section near the pressure flume. A vent pipe extending above head water is included with the penstock.

4. STRUCTURAL SUPPORTS FOR CASE.

Two 12" x 31.5 pound I-beams, each 15'-0" long and four cast iron case brackets will be furnished to support the old pressure case in its new location.

5. POWER TRANSMISSION EQUIPMENT.

To transmit the power to the generator floor, the Company proposes to furnish the following material:

1 - Double arm split cast iron sheave, 70" P.D. with 25 grooves.

1 - Double arm split cast iron sheave, 34" P.D. with 25 grooves.

1 - Split winder sheave, 34" P.D.

1 - 54" Frame - Horizontal double track tension carriage complete with -

1 - 49" P.D. Single groove sheave.

100 pound tension weights.

1 - Weight rod.

1900 feet of 1", 4 strand Manila transmission rope.

Necessary tracks for tension carriage.

Both the driver and driven sheave will have 25 grooves each and a winder sheave will run loose beside the 34" sheave, from which one strand will lead to the tension carriage sheave, which in turn will deliver that strand back to the first groove on the 34" wheel. The overall width of these two wheels will be 40-7/8".

6. GOVERNOR CONNECTIONS.

It is intended to use the present Woodward mechanical type "C" governor in the new powerhouse. The Company proposes to furnish the necessary drives and pulleys to make the governor installation adaptable to its new location.

Respectfully submitted,

S. MORGAN SMITH COMPANY

By Arthur Young

SPECIFICATIONS NO. 18369-B.

1. GENERAL DESCRIPTION.

This specification is intended to cover the design and construction of two trash racks as shown on the Company's drawing P-1063-J-1.

2. MATERIAL FURNISHED.

The total width of each trash rack will be 15'-0" with a height of 21'-6". Seven sections of rack will be furnished for each flume. The bars will be 2½" x ½" and will be located on 1½" centers and held rigid by pipe spacers. One Z-bar and three I-beams, each 15'-0" long, all of sufficient strength for holding each trash rack in place will be furnished.

Respectfully submitted,

S. MORGAN SMITH COMPANY

By Arthur Young

SPECIFICATION NO. 18369-C.

1. GENERAL DESCRIPTION.

This specification is intended to cover the design and construction of two structural steel gates with structural steel guides and anchorage for controlling the water supply to the flume which will contain the single vertical adjustable blade turbine as shown on the Company's drawing P-1063-J-1.

2. DETAIL DESCRIPTION.

Each gate will be 7'-6" wide by 16'-6" high. The cross members will consist of six 6" x 12.5 pound I-beams and two 6" x 10.5 pound channels each 7'-3" long. The cover plate will be 7'-6" by 16'-6" and will be fabricated from 1/4" plate. Steel wearing strips will be furnished where the gate rides against the structural guide.

The frames for both gates will consist of two 12" x 20.7 pound channels, each 27'-0" long; one 18" x 60 pound I-beam 27'-0" long and four 3" x 3" x 7/16" angles each 27'-0" long.

A slide type, hand operated filling gate will be provided to balance the pressure on both

sides of the head gate so that the hoist need be only of capacity sufficient to lift the weight of the gate itself.

Respectfully submitted,

S. MORGAN SMITH COMPANY

By Arthur Young

SPECIFICATION NO. 18369-D.

1. GENERAL DESCRIPTION.

This specification is intended to cover the design and construction of one structural steel head gate with structural steel guides and anchorage for controlling the water supply to the old horizontal steel pressure flume unit which will be installed in the new power house.

2. DETAIL DESCRIPTION.

Each gate will be 7'-6" wide by 10'-0" high. The cross members will consist of six 6" x 12.5 pound I-beams and two 6" x 10.5 pound channels each 7'-3" long. The cover plate will be 7'-6" x 10'-0" and made of 1/4" plate steel. Wearing strips will be provided where the gate rides against the guides.

The frame will consist of two 6" x 10.5 pound channels each 17'-6" long and two 6" x 10.5 pound channels each 8'-0" long.

A slide type, hand operated filling gate will be furnished to equalize the pressure on both sides of the gates.

Respectfully submitted,

S. MORGAN SMITH COMPANY

By Arthur Young

June 19, 1931.
Aug. 1, 1931.

S. Morgan Smith Company, York, Penna.

Proposal No. 6608

THIS PROPOSAL, Made this 11th day of May 19 31, by the S. MORGAN SMITH COMPANY, of York, Pennsylvania, hereafter known as the COMPANY, to and on behalf of City of Martinsville, Va.

known as the PURCHASER.

WITNESSETH:—The COMPANY agrees to sell to the PURCHASER the following machinery, to wit:

	Spec'n.	Item No.
One (1) Vertical unit complete with governor	18369	1
Necessary repairs to old horizontal unit	18369-A	2
Trash racks for two flumes	18369-B	3
Two (2) head gates for vertical unit	18369-C	4
One (1) head gate for horizontal unit	18369-D	5
One (1) 4 ton electric trolley hoist.		6

All to be in accordance with the specifications Nos. as noted above and guarantees set forth in the proposal of the COMPANY hereto annexed, and which are hereby made a part of this proposal. The same to be delivered free on board cars York, Pennsylvania, with freight allowed to Martinsville, Va.

Shipments of this machinery will be made as follows:

Parts to be embedded in concrete with 2½ months.

Complete shipment in 3 months.

The time named for shipment is determined by the date of receipt of order and is contingent on receipt of full information necessary to complete detail drawings; and any delay in receipt of necessary information will extend the shipping date equal to such delay.

Definitions

I. In this proposal wherever the word "Engineer" is used, it shall mean the Engineer or Engineers of the Purchaser, except where used under Article IX. Wherever the word "Work" is used, it shall mean all of the materials, unless the contents requires a different meaning, together with the necessary labor to be performed by the Company required to complete the construction of the machinery herein described.

Quality of Work

II. All the machinery, unless otherwise specified in this contract, shall be constructed of first class materials of their several kinds, shall be finished in a workmanlike manner, and shall conform to the specifications.

Drawings and Information

III. It is mutually agreed that after receipt of the necessary information from the Purchaser, or his Engineer, the Company will prepare general arrangement drawings of the machinery in elevation and plan, and will submit the same for approval. It is also mutually agreed that the Purchaser and/or his Engineer shall be responsible for the net effective head of water under which the turbine operates, for the elevations of head and tail water, for the quantity of water available to operate the turbines and for the exactness and completeness of the information pertaining thereto given to the Company. The Purchaser, or his Engineer, shall furnish the Company such information as may be reasonably required to produce properly designed and manufactured equipment. The drawings furnished by the Company shall be sufficiently complete and shall give the necessary dimensions to enable the Purchaser to proceed with the design and construction of the power house for the accommodation of the machinery. The approval of the drawings on the part of the Purchaser or the Engineer shall not relieve the Company from its obligations under the contract, nor from responsibility for any errors in the drawings, provided however that such errors do not originate in the information given to the Company by the Purchaser or his Engineer.

Change of Design

IV. It is agreed that any changes in, or additions to, the work included in this contract, which may be mutually agreed upon in writing, between the Purchaser, the Engineer and the Company during the progress of the work, shall become effective and accepted by the Company and paid for by the Purchaser at a price to be mutually agreed upon in writing, between the Company and the Purchaser or the Engineer; provided, however, that whenever such changes or additions involve the abandonment of work commenced or in process of completion, the Purchaser shall adequately

reimburse the Company for all losses of labor and material and for the expense incurred in making such changes. If changes involve an increase in the cost of the work, the increase shall be borne by the Purchaser; if a decrease, it shall be credited to the Purchaser by the Company.

Shipment

V. As the work is completed the Company will give due notice to the Purchaser of each shipment, together with full information as to routing, car numbers and as far as possible approximate weights of the various parts.

It is agreed that the Company shall, under no circumstances or in any event, be held responsible or liable, for any loss, damage, detention or delay caused by delays of carriers, fire, strike, lockouts, civil or military authority, or by insurrection or riot, or by such other occurrences as are usually termed "acts of God," and that the receipt of machinery by Purchaser on its arrival shall constitute a waiver of all claims for damages on account of delays in shipment or otherwise.

If the shipment of the machinery herein specified, or any parts thereof, is delayed by any causes beyond the Company's reasonable control or for which the Company is not responsible, the date of completion of said machinery by the Company shall be regarded as the date of shipment in determining when payments for said machinery are to be made, and the Company shall be entitled to receive the customary compensation for storage, such storage to be at the Purchaser's risk. In all cases where all the machinery shall not be forwarded on the same date, pro rata payments shall be made for partial shipments.

Inspection

VI. The Company shall give to the Purchaser, or his Engineer, free access to its works during working hours, and shall furnish them with such information as may be necessary from time to time, as to materials used, the process of manufacture, and progress of the work, and shall afford full facilities for the inspection, as may be required by Purchaser or his Engineers.

Erection

VII. On request by the Purchaser, the Company will supply one or more superintendents for services in installing the machinery herein specified, whose compensation shall be at the rate of Fifteen (15.00) Dollars per day each, not exceeding ~~eight~~ JER (10) hours, double time for Sundays and legal Holidays, and time and a half for all other overtime, plus their living and traveling expenses to and from York, Pennsylvania. This time is to commence when they leave York and cease when they return,

they to use due diligence in making the trip. The time and expenses of the superintendents shall be paid for by the Purchaser monthly and independent of the contract price. It is understood and agreed, that during the term of such service the said superintendents shall be the Purchaser's employees, and the Purchaser shall indemnify and save harmless the Company from all claims and liabilities, arising out of the acts of the said superintendents of erection. All rigging, tools and appliances, together with skilled and common labor for the safe and efficient handling shall be supplied at the expense of the Purchaser.

It is understood and agreed that the Company shall not be held responsible for any damage to the apparatus during the unloading and erection of the work under this contract; but that when the erection is carried out under the supervision and pursuant to the directions of the Erecting Superintendents aforesaid, the Company warrants that the work of erecting, assembly and adjustment of the machinery shall be in accordance with the plans and specifications.

Tests

VIII. Within three months after the machinery shall have been placed in operation, tests shall be made at the expense of the Purchaser for the purpose of determining if it meets the conditions set forth in the contract and specifications. The performance of said machinery as to power, speed and efficiency, shall be determined by a test of one or more units to be selected jointly by the Purchaser and the Company. The test shall be carried out in accordance with the testing code, hereto attached, which it is mutually agreed shall form a part of these specifications. If the machinery fulfills the contract and conforms to the general design, it shall be promptly accepted by the Purchaser. Before making the test the Purchaser shall give the Company reasonable notice of same, and the Company reserves the right to have representatives present at the test, and also the right to witness the tests of the generators or other driven machinery and calibration tests of all instruments.

Prior to the acceptance of the machinery by the Purchaser, the Purchaser shall, at his own expense, whenever requested by the Company, shut off the water and permit the inspection, adjustment, repair or alteration of any part of the machinery furnished hereunder.

If for any reason whatsoever, the machinery fails to meet the guarantees in any respect, the Company shall have the right to make such alterations as may be required in order that the performance of the machinery shall conform to the guarantees. The expense of additional tests beyond the original tests called for hereunder, required to show the effect of such alterations, shall be borne

by the Company; this expense, however, shall include only the direct expenses of the men engaged in the test and the cost of setting up the test equipment, and shall not include the value of power lost or maintenance costs of the power station, loss of income, or any other expense or consequential damage.

If for any reason the machinery sold should fail to do the work for which it was designed and constructed, the Company shall in no event be held liable for consequential damages and its liability shall in no case exceed the sum of all payments received from the Purchaser.

Arbitration

IX. Any controversy or claim arising out of or relating to this contract or the breach thereof, shall be settled by arbitration, in accordance with the Rules, then obtaining, of the American Arbitration Association, and judgment upon the award rendered may be entered in the highest court of the forum, state or federal, having jurisdiction.

Defective Parts

X. In the event any part of said machinery shall prove defective within one year from the date of shipment, and the same is proven to have been defective at the time of shipment, and the Purchaser gives the Company immediate written notice of the defects, the Company agrees to furnish without charge, F. O. B. cars its works, a similar part free of expense to the Purchaser. No allowance shall be made to the Purchaser for repairs or alterations, unless the work is done with the written consent and approval of the Company. The Company shall not be held responsible for excessive wear, deterioration and breakage, or for other damage to any of the parts of said machinery due to their improper use on the part of the Purchaser or for failure of foundations, foreign substances or impurities in the water or for other causes beyond the control of the Company.

Title

XI. It is expressly agreed that the title and ownership of the property called for and furnished under the terms of this contract shall remain in the Company, notwithstanding the method of its attachment to the realty or otherwise, until the full and final payment thereof shall have been made by the Purchaser, according to the terms agreed upon, and notes, if any, shall have matured and been settled for in full, in cash. In case of default in any of the payments above provided, the Company may repossess itself of the above mentioned property, wherever found, and shall not be liable in any action of law, on the part of said Purchaser, and the Purchaser agrees to put no obstacle in the way of the Company in repossessing itself of its property. It is also agreed that the Pur-

chaser shall be responsible for any damage or loss, by fire or otherwise, to the machinery after shipment.

The Purchaser agrees to execute any papers necessary to legalize the retention of title by the Company in any state or country in which the apparatus may be located.

Patents

XII. The Company shall, at its own expense, defend any suits that may be instituted by parties against the Purchaser for alleged infringement of patents, pertaining to said machinery, provided the alleged infringement shall consist in the use of said machinery or parts thereof in the regular course of the Purchaser's business, and provided the Purchaser shall have made all payments then due under this contract, and gives to the Company immediate notice in writing of the institution of such suits, and permits the Company to defend the same, and gives all needed information, assistance and authority to enable the Company so to do. The Company shall not be responsible for any compromise made by the Purchaser, without its written consent, nor shall it be bound to defend any suit or to pay any damages therein, if the same shall arise by reason of the use of parts not furnished by the Company.

Insurance

XIII. The Purchaser shall provide and maintain in the name of the Company adequate insurance against loss or damage by fire for the machinery herein specified, said insurance to take effect upon shipment of all or any part of said machinery, and to be in an amount fully protecting the Company. In the event the Purchaser fails to procure such insurance, the Purchaser assumes all losses resulting thereby. In the event of loss by fire before shipment, the Company agrees to indemnify the Purchaser for moneys paid on account of the contract.

Contract Price

XIV. The Purchaser hereby agrees to pay to the Company as compensation for the full performance of this contract, in accordance with the specifications hereto attached, the sum of.....

Twenty One Thousand Six Hundred Twenty Three ($21,623.00) Dollars which price covers Items 1 to 6 inclusive. See Page 6-A.

free of exchange as provided in Article XV of this proposal.

ITEM NO. 1.

One (1) vertical adjustable blade hydraulic turbine complete with governor and pumping equipment, all in accordance with Specification No. 18369.

ITEM NO. 2.

New parts for the present horizontal steel pressure flume turbine, all as described under Specification No. 18369-A.

ITEM NO. 3.

Two (2) structural steel trash racks in accordance with specification No. 18369-B.

ITEM NO. 4.

Two (2) structural steel head gates and guides, as described under Specification No. 18369-C.

ITEM NO. 5.

One (1) structural steel head gate and guide as described under specifications No. 18369-D.

ITEM NO. 6.

One (1) 4 ton electric hoist with hand geared trolley, lifting speed 14 feet per minute, height of lift 20 ft. Motor to be G. E. type fully enclosed. Controller to be of drum type - pendent rope control. This hoist to be used for operating the head gates in front of the turbines.

Terms of Payment

XV. Sixty per cent. (60%) of the contract price in cash upon presentation of shipping documents. Thirty per cent. (30%) thirty days from date of shipment. Ten per cent. (10%) sixty days from date of shipment.

The deferred payment to be closed by Bank Acceptances at the time of presentation of shipping documents.

The payments as above specified shall not relieve the Company of its responsibility under the terms of the contract.

"It is mutually agreed by the parties hereto that in the event the Company is prevented from completing or shipping the machinery specified in this contract, or from otherwise fulfilling its part of this contract, because of any act of the Purchaser over which the Company has no control, then and in that event, the payments as herein provided shall be made by the Purchaser and the date of shipment specified in the contract shall be regarded as the date of actual shipment for the purpose of determining when the payments for said machinery are to be made. Any expenses incurred by the Company by reason of the Purchaser not receiving or holding up shipments of the machinery, or delaying the completion of the machinery by the Company, shall be paid by the Purchaser, together with reasonable compensation for storage, which storage is to be at the risk and expense of the Purchaser."

In the event all machinery covered by the contract shall not be shipped on the same date, payment shall be made for partial shipments pro rata.

All payments deferred for any reason whatsoever beyond the date covered by the contract, shall bear interest from such date, at the rate of 6%, except when such payments are withheld on account of defects in the machinery, and when such defects actually prevented operation of the machinery.

Amendments

XVI. The foregoing is the agreement between said parties as it exists at this date, and it is agreed that all previous communications between said parties, either verbal or written, contrary to the provisions hereof, are hereby withdrawn and annulled; and the express warranties herein contained are in lieu of all implied warranties; and that no modification of this agreement shall be binding upon the parties hereto, or either of them, unless such modifications shall be in writing duly accepted by the Purchaser and approved by an executive officer of the Company.

TESTING CODE

(Approved by Machinery Builders' Society, Oct. 11, 1917.)

Intended Scope.

1. Hydraulic turbine tests are of two distinct kinds; first, acceptance tests on completed turbines after installation in the power plant; second, experimental tests either on full-sized turbines or models, carried out at manufacturers' laboratories or at a testing flume. Tests of the first kind are for the purpose of determining the fulfillment or non-fulfillment of contracts between the turbine builders and the purchasers. Tests of the second kind are carried out for the purpose of obtaining experimental data on which the design of an installation may be based; for scientific research work; or for the investigation of special problems. This code is intended to apply only to tests of the first kind. When tests of the second kind are used for determining the performance of a full-sized installation, this application should be made only in accordance with principles which will be stated in Section 10, below.

Principal Factors, Meaning and Intent of Terms Used.

2. Incomputing the efficiency of an installation a distinction must be made between the efficiency of the plant and the efficiency of the turbine. The efficiency of the plant may include all losses of energy up to any stated point of delivery, such as the delivery of electric power from the transformers, at the switchboard or at the generator terminals, or may be confined to the total efficiency of the hydraulic installation for which purpose the power is to be computed as that delivered by the turbine to the generator shaft.

For the purpose of computing the plant efficiency the total or gross head acting on the plant is to be used, and is to be taken as the difference in elevation between the equivalent still water surface before the water has passed through the racks, to the equivalent still water surface in the tailrace after discharge from the draft tube. When the water in the forebay in advance of the racks flows with sufficient velocity to make its velocity head an appreciable quantity, the actual elevation of the water surface shall be increased by the amount of this velocity head. The same process shall apply to the point of measurement in the tailrace, that is: the velocity head at the point of measurement in the tailrace shall be added to the actual elevation of the surface, the sum being considered the equivalent still water elevation.

Principal Factors, Meaning and Intent of Terms Used. (Cont'd)

Except where specifically stated herein, this code shall be understood to apply to tests of the turbine proper, and the terms power, efficiency, effective head, etc., are to be taken as referring to the turbine. In computing the efficiency of the turbine, the losses through the racks, in the intake to the penstocks, and in the penstocks shall not be charged against the turbine; nor shall the head necessary to set up the velocity required to discharge the water from the end of the draft tube be charged against the turbine. The net or effective head acting on the turbine shall be measured from a point near the intake to the turbine casing in turbines equipped with casings, or from a point immediately over the turbine in turbines having an open flume setting, to a point in the tailrace in the manner set forth below under the heading "Measurement of Head." Since the turbine cannot develop power without discharging water, a correction for the velocity head required to discharge the water into the tailrace shall be added to the tailwater elevation; and a similar correction applied at the intake to encased turbines, as called for under the heading "Measurement of Head." The power developed by the turbine shaft and transmitted by the turbine shaft to the generator or other driven machine or system.

It has been customary in certain classes of turbines, to determine the performance of the turbine exclusive of the casing. The results of such determination represent the performance of the guide vanes, runner, draft chest and draft tube only, and when contracts are made on this basis, Section 8(a) herein shall be modified to exclude the velocity head at entrance to the casing, and the pressure shall be measured by piezometers so located on the casing as to avoid velocity effects, instead of at entrance to the casing as therein specified.

In drawing up a general code it is recognized that under particular circumstances sometimes occurring, methods of measuring or computing certain factors entering into the test different from those specified, may appear possible and reasonable; it is however the intent of this code that the meaning of the terms efficiency, effective head, etc., shall be the efficiency, effective head, etc., determined as herein specified, and that such terms shall be understood only as thus defined.

General.

Inspection.

3. Careful inspection shall be made before, during and after the tests to insure the proper operation of the turbine and conditions of measurement.

The turbine runner, guide vanes and casing should be inspected before and after test to guard against obstructions clogging the vanes. And change in performance during a test should be investigated.

Operating Conditions During Test.

4. Apparatus installed for the purpose of the test shall not affect the performance of the turbine during the test. When any doubt exists regarding this point, a special experiment shall be carried out to detect any effect of removing and replacing the apparatus in question, other conditions being maintained constant.

The unit shall be in normal operating condition throughout the test, and shall have been operated under load for an aggregate time of at least 3 days prior to the test.

Leakage.

4(a). Care should be taken that all air inlets into the draft tube are closed, and that leakage of air into the tube or drawing of air into the penstock intake is not taking place, as indicated by excessive amounts of air in the discharge, or presence of vortices in the intake. Precautions against leakage of water from penstock or turbine casing should be taken, particularly through drain valves, relief valves or other connections. The rate of fall of the standing water surface in the turbine casing below the point of intake through the turbine gates should be observed during shut-down as an indication of possible leakage.

Unsteady Conditions.

4(b). Tests should not be made under conditions of changing head, load or speed. Variations of load during an individual run shall not exceed 3% above or 3% below the average load, and variations of head shall not exceed 2% above or 2% below the average head, and variations of speed shall not exceed 1% above or 1% below the average speed. Instrument calibrations and correction curves should be prepared in advance of the test, and measures taken to enable results to be computed as quickly as possible during the course of the test or before the work of testing shall be considered to have been completed.

Calibration of Instruments.

5. Important instruments shall be installed in duplicate and all instruments shall be calibrated both before and after the test. Only the readings of those instruments in which the two calibrations agree shall be used in computing the results. Where results are appreciably altered by reason of instrument calibrations made after the test disagreeing with those made before, the test shall be repeated.

Conduct of Test.

6. Both parties to the contract shall be represented and shall have equal rights in determining the methods and conduct of the test.

All points of disagreement shall be settled to the satisfaction of both parties, and the results of the test be agreed on as acceptable, before the test shall be considered terminated or the test equipment removed.

The measurement of the various quantities entering into the computation of turbine power and efficiency shall be in accordance with the following regulations:

Measurement of Power Output.

By Electrical Measurement of Generator Output and Generator Losses.

7(a). In turbines direct-connected to electrical generators the power output of the turbine may be measured as provided below.

The intent of the provisions contained herein is that the power output of the turbine shall be taken as the power output of the generator plus all losses supplied by the turbine up to the point of measurement.

The generator may be tested for efficiency either in the shops of the builder or after installation, the losses being determined either by direct measurement of input and output or by the separate loss method; the electrical measurements being carried out in accordance with the Standardization Rules of the American Institute of Electrical Engineers of September, 1916, but subject to the provisions contained herein.

The generator losses and efficiency as herein defined are for the generator considered as a dynamometer, and are independent of

By Electrical Measurement of Generator Output and Generator Losses. (Cont'd)

the performance guarantees of the generator which are not within the scope of this Code. The generator efficiency shall be determined for the values of load, power factor, temperature or other conditions existing during the turbine test. When the generator is run during the turbine test at speeds different from that used in the generator test, the generator efficiency shall be corrected for the changes in speed.

When practicable the generator is to be separately excited during both generator and turbine tests, and the excitation loss is not to be included in computing generator efficiency, and is therefore also to be omitted in computing turbine output during the turbine test.

When determined by the separate-loss method, the generator efficiency in the case of polyphase alterations when separately excited is to be taken as

$$\frac{\text{(Kilowatt output at generator terminals)}}{\left(\begin{smallmatrix}\text{Kilowatt}\\ \text{output}\end{smallmatrix}\right) + \left(\begin{smallmatrix}I^2R\\ \text{armature}\end{smallmatrix}\right) + \left(\begin{smallmatrix}\text{Open circuit}\\ \text{core loss}\end{smallmatrix}\right) + \left(\begin{smallmatrix}\text{Stray}\\ \text{load-losses}\end{smallmatrix}\right) + \left(\begin{smallmatrix}\text{Generator windage}\\ \text{and friction}\end{smallmatrix}\right)}$$

all losses being expressed in kilowatts.

The stray load-losses are to be determined, in accordance with Paragraph 458 of the above Standardization Rules of the A. I. E. E., by operating the generator on short circuit and at the current corresponding to the load to be used in turbine test. This, after deducting the windage and friction and I^2R loss, gives the stray load-loss, the total amount of the loss so determined being included in the above formula, in place of ½ or ⅓ of this value as sometimes used in former practice. It is, however, understood that whenever under the special conditions of an installation other losses exist, these are to be added, in accordance with the second paragraph of this subdivision, to the stray load-losses determined as here given.

The value of generator windage and friction should be directly measured in the shop, or after installation. In units containing direct-connected exciters, the windage and friction may be measured by driving the generator by the exciter run as a motor. When the windage and friction cannot be directly measured, it is to be taken either from shop tests of generators of similar design or from a retardation test made after installation. When possible more than one method should be used in order to obtain a check.

In making such a retardation test, the turbine shaft and runner, or the turbine runner, are to be disconnected when practicable from the generator shaft, in order to enable the windage and friction of the generator alone to be computed. When the turbine shaft or runner cannot be disconnected, the generator windage and friction are to be computed by deducting from the total windage and friction that of the turbine, which for this purpose may be found with sufficient accuracy from the formula:

Turbine windage and friction in $KW = KBD^4N^3$, in which

B = height of distributor in feet,

D = entrance diameter of runner in feet, at centerline of distributor;

N = revolutions per second,

K = an empirical coefficient which may be taken as 0.000115 as determined from available test data.

In computing the turbine output in the turbine test, this is to be taken as the kilowatt output of generator divided by the generator efficiency as computed above, the result being converted from kilowatts to horsepower.

If an exciter generator is also mounted on the unit shaft and is used to excite the unit under test, then to the output of the main generator computed as above without reference to excitation there is to be added the kilowatt output of exciter divided by the exciter efficiency, this converted to horsepower. It is recommended, however, for simplicity that when possible the exciter shall be run without load and the unit separately excited.

It is recommended, to avoid retests and to provide a reliable check, that the electrical instruments used in all tests be installed in duplicate. These instruments, together with the instrument transformers, shall be calibrated both before and after the tests in the same condition as used in the tests. When tests are made under slightly fluctuating loads, the output shall be determined both by indicating wattmeters, read at short intervals, and by recording watthour meters. During the turbine test the speed of the unit shall be observed by accurately calibrated tachometer or by revolution counter.

By Absorption Dynamometer.

7(b). When a dynamometer, either of the Prony brake, friction disc or other type is used, the dynamometer is to be so arranged as to avoid imposing either end thrust or side thrust on

By Absorption Dynamometer. (Cont'd)

the turbine shaft and bearings, or to avoid adding any friction load which is not measured.

The brake must be capable of operating with the weighing beam floating free of the stops during the entire duration of a run. A dash pot or equivalent device may be used to assist this action if so arranged that the accuracy of measuring the actual torque acting on the turbine shaft is not impaired.

The dynamometer must be so constructed that the lengths of all lever arms used for transmitting and reducing the loads can be accurately measured. The zero load of the dynamometer must be capable of accurate measurement and should not be large in comparison with the net load to be measured.

When power is determined by dynamometer, particular care is to be used in obtaining accurate measurement of the speed of the shaft. If tachometers are used these are to be frequently calibrated by counting the revolutions over an ample length of time. Under usual conditions it is recommended that the speed be directly measured by revolution counter, a tachometer being also used as a check and to indicate variations in speed during a run.

Measurement of Power Input or Water Horsepower.

Measurement of Head.

8. The intent of the provisions contained herein for the measurement of head is the true determination of the difference between the total energy contained in the water immediately before its entrance into the turbine, and its total energy immediately after its discharge from the draft tube.

The turbine shall be tested, if possible, under the effective head stated in the contract, and at the speed specified in the contract. If during the test, however, the effective head shall differ from the specified head by an amount not exceeding 10 per cent. of the latter, the speed of operation of the turbine shall be adjusted to correspond to the head under which the test is made. The principle is recognized and accepted that if the speed is changed in proportion to the square root of the head, the horse-power output will change in proportion to the three-halves power of the head and the turbine efficiency will remain the same; that is: when the head differs from the value specified in the contract, the contract guarantees shall be considered to apply if the hydraulic equivalents of the

Measurement of Head. (Cont'd)

power and speed of the turbine are substituted for the power and speed enumerated in the contract. The hydraulic equivalent of the speed is equal to the specified speed multiplied by the square root of the ratio of the effective head existing during the test to the specified effective head. The hydraulic equivalent of the horsepower is equal to the specified horsepower, multiplied by the square root of the ratio of the effective head existing during the test to the specified effective head. The hydraulic equivalent of the horsepower is equal to the specified horsepower, multiplied by the three-halves power of the ratio of the effective head existing during the test to the specified effective head.

The tests shall not be carried out if the head differs from the contract value by more than 10 per cent. either above or below, or if, due to an excess of the head above the contract value, or to a reduction in tailwater elevation, the total draft head approaches within 5 feet of the limiting value corresponding to the barometric height. By total draft head is meant the height of the centerline of the distributor of vertical turbines, or of the highest point of the discharge space of the runner of horizontal turbines, above tailwater, added to the velocity head at the point of minimum internal diameter of the runner band.

If during the test it is not practicable to adjust the speed, or if the final calculation should show the speed to have been incorrectly adjusted to suit the head, provided that the discrepancy in speed does not exceed 2 per cent. either way from the correct value, the values of power and efficiency shown by the test shall be corrected on the basis of the test curves, of the same or a homologous turbine, made at a testing flume or on a wheel tested in place according to the methods of this code, when such curves are available.

Encased Turbines.

8(a). In turbines having closed casings the head is to be measured by at least two, and when possible not less than four piezometers located in a straight portion of the penstock near the turbine casing intake, and by two or more board, rod or float gages in the tailrace, place at points reasonably free from local disturbances.

Such board, rod or float gages are to be free of velocity effects, and if this is not obtainable when the gages are set in the open channel, they shall be placed in properly arranged stilling boxes.

All piezometers shall be connected to separate gages. The conditions of measurement, including velocity distribution, length of

Encased Turbines. (Cont'd)

straight run of penstock, and conditions of piezometer orifices shall be such that no piezometer shall vary in its readings by more than 20 per cent. of the velocity head from the average of all the piezometers in the section of measurement. The piezometer orifices shall be flush with the surface of the penstock wall, the passages shall be normal to the wall, and the wall shall be smooth and parallel with the flow in the vicinity of the orifices. The piezometer orifices shall be approximately ¼" in diameter. If any piezometer shall be obviously in error due to some local cause or other condition, as indicated by its reading, after the addition of the velocity head, giving a head in excess of the initial available head corresponding to the elevation of the surface of headwater, the source of the discrepancy shall be found and removed, or the piezometer eliminated.

When stilling boxes are used in the tailrace the communication between the box and channel shall consist of one or more piezometer openings in a plane surface parallel to the flow, in order to avoid velocity effects. When board gages are used at the side of the channel, they shall be flush with the wall surface.

The effective head on the turbine is to be taken as the difference between the elevation corresponding to the pressure in the penstock near the entrance to the turbine casing, and the elevation of the tailwater at the highest point attained by the discharge from the unit under test, the above difference being corrected by adding the velocity head in the penstock at the point of measurement and subtracting the residual velocity head at the end of the draft tube. The velocity head in the penstock shall be taken as the square of the mean velocity at the point of measurement, divided by $2g$; the mean velocity being equal to the quantity of water flowing in cubic feet per second, divided by the cross-sectional area of the penstock at the point of measurement in square feet. The residual velocity head at the end of the draft tube shall be taken as the square of the mean velocity at the end of the draft tube, divided by $2g$; the mean velocity being equal to the quantity flowing in cubic feet per second, divided by the final cross-sectional discharge area of the closed or submerged portion of the draft tube in square feet.

Open Flume Settings.

8(b). In the case of turbines set in open flume, the head is to be measured by board, rod or float gages located immediately above the center of the turbine, and by board, rod or float gages in the tailrace, all gages being placed at points reasonably free from

Open Flume Settings. (Cont'd)

local disturbances, and not less than two gages being installed in the flume and not less than two in the tailrace.

Such gages are to be free of velocity effects, and if this is not obtainable when the pages are set in the open channel, they shall be placed in properly arranged stilling boxes. When stilling boxes are used, the communication between the box and channel shall consist of one or more piezometer openings in a plane surface parallel to the flow, in order to avoid velocity effects. When board gages are used at the side of the channel, they shall be flush with the wall surface.

The effective head on the turbine is to be taken as the difference between the elevation of the free water surface immediately above the center of the turbine, and the elevation of the tailwater at the highest point attained by the discharge from the unit under test, the above difference being corrected by subtracting the residual velocity head at the end of the draft tube. The residual velocity head at the end of the draft tube shall be taken as the square of the mean velocity at the end of the draft tube, divided by 2g; the mean velocity being equal to the quantity flowing in cubic feet per second, divided by the final cross-sectional discharge area of the closed or submerged portion of the draft tube, in square feet.

Measurement of Quantity of Water.

9. The quantity of water discharged from the turbine is to be measured by one of the following methods. It is recommended that whenever possible more than one of these methods be used, the quantity being taken as the average of the results of two or more simultaneous measurements.

By Weir.

9(a). When the quantity of water is measured by weir, weirs with suppressed end contractions shall be used.

The weir or weirs shall if possible be located on the tailrace side of the turbine, and care shall be taken that smooth flow, free from eddies, surface disturbances or the presence of considerable quantities of air in suspension, exists in the channel of approach. To insure this condition the weir should not be located too close to the end of the draft tube, and stilling racks and booms should be used when required. The channel of approach should be straight, of uniform cross-section and should be unobstructed by racks and booms, for a length of at least 25 feet from the crest.

By Weir. (Cont'd)

The racks should be arranged to give approximately uniform velocity across the channel of approach. The uniformity of velocity should be verified by current meter or otherwise.

The head on the weir should be observed by hook gages placed in stilling boxes communicating through orifices approximately 1 inch in diameter in the sides of the channel of approach, approximately 1 foot below the level of the crest and a distance of not less than five or more than ten times the head upstream therefrom, the head being observed independently at both sides of the channel. In measuring quantities of water corresponding to the loads on which the turbine guarantees are based, the head on the crest shall not be more than two (2.0′) feet or less than one (1.0′) foot, and the velocity of approach shall not be greater than 1.5 feet per second.

The discharge shall be computed by the Francis formula in the form given below, using the accompanying table of coefficients. These coefficients are believed to represent the best available information. The values of turbine efficiency resulting from weir tests made in accordance with this code are understood to be efficiencies computed by the use of the formula and coefficients here given.

$Q = CLh^{3/2}$ where Q = Quantity in cubic feet per second,
L = Length of weir in feet,
h = Observed head above crest in feet.

TABLE OF VALUES OF C FOR VARIOUS HEADS AND HEIGHTS OF CREST p.

Head	*Height of crest p*										
h	4	5	6	7	8	9	10	12	14	16	20
1.0	3.376	3.356	3.344	3.335	3.329	3.325	3.322	3.317	3.314	3.311	3.308
1.2	3.391	3.366	3.350	3.339	3.332	3.326	3.322	3.316	3.311	3.308	3.305
1.4	3.409	3.378	3.359	3.346	3.336	3.330	3.324	3.316	3.311	3.307	3.303
1.6	3.429	3.392	3.370	3.354	3.343	3.334	3.328	3.319	3.312	3.308	3.302
1.8	3.450	3.408	3.382	3.363	3.350	3.340	3.333	3.322	3.315	3.309	3.303
2.0	.....	3.425	3.394	3.373	3.358	3.347	3.338	3.325	3.317	3.311	3.304

By Weir. (Cont'd)

p is the height of the crest above the bottom of the channel of approach, in feet.

To facilitate computations, all corrections for velocity of approach have been included within the coefficients as given; these are therefore to be used in the formula stated above, the observed head being used without modification.
Note: The above coefficients are the averages of values computed by the following three formulæ:

(1) Bazin, $Q = \left(0.405 + \frac{0.00984}{h}\right)\left[1 + 0.55\frac{h^2}{(p+h)^2}\right]\sqrt{2g}\,L\,h^{\frac{3}{2}}$;

(2) Rehbock, $Q = \left[0.605 + \frac{1}{320h-3} + 0.08\frac{h}{p}\right]\frac{2}{3}\sqrt{2g}\,L\,h^{\frac{3}{2}}$;

(3) Fteley-Stearns, $Q = 3.31\,L\,(h + 1.5h_v)^{\frac{3}{2}} + [0.007L$, in which
h_v = head due to velocity of approach

The weir shall be sharp crested, with smooth, vertical crest wall, complete crest contraction, and free overfall. Complete aeration of the nappe shall be secured and observation of the crest conditions and form of nappe shall be made during the test to avoid defective conditions such as adhering nappe, disturbed or turbulent flow, or surging. The sidewalls of the channel shall be smooth and parallel and shall extend downstream beyond the overfall above the level of the crest.

Weirs of a length exceeding approximately twenty times the head (excepting in cases where the velocity of approach is extremely low); or weirs of moderate crest length having high velocities of approach; or those in which the velocity of approach is irregularly distributed, or in which the leading channel is subject to action of the wind, should either be sub-divided into a number of sections or the head should be observed not only at both sides but also at intermediate points across the channel of approach. The elevation of the crest should be measured at short intervals of its length in determining the zero readings of the hook gages.

By-Current Meter.

9(b). When the discharge is measured by current meter, observations shall be taken by two different types of meter, one type having preferably such characteristics that it will slightly over-register under conditions of turbulent or oblique flow, and

By Current Meter. (Cont'd)

the other type having characteristics such that it will under-register under similar conditions. The true velocity obtained by reducing the meter readings on the basis of their still-water ratings may then be taken as a weighted mean between the two series of observations.

As a basis for arriving at the proper weighting of diverging meter results, the instruments in question should, in adition to their regular still-water ratings, be given simultaneous oscillation or angularity tests at several velocities near those which will probably be experienced during tests. By means of the resulting data, curves showing the over- and under-registering characteristics of each meter may be plotted for varying degrees of obliquity or velocities of oscillation. The total deviation of the two meters may then be noted for any obliquity or lateral velocity. When the relative deviation of the two meters is observed in the field, the curves will then indicate the proportions in which the total deviation should be divided to give the proper correction for each meter.

The point method of observation shall be used and sufficient points shall be obtained to enable both vertical and horizontal velocity curves to be plotted for all portions of the section of measurement. The average velocity shall be determined from these curves by planimeter.

The section of measurement shall be rectangular and smooth flow conditions shall be obtained. It is recommended that in order to avoid abnormally long durations of run a number of meters of each type be used simultaneously. The elevation of water shall be continuously observed during the current meter measurement by stilling boxes, piezometers or other reliable means. If the supporting rods for the meters are in the same plane as the meters, the area of these rods shall be subtracted from the wetted area of the flume in calculating the quantity. The meter should preferably be supported by rods placed a sufficient distance behind them to avoid any obstructive effect. When a heavy mast or supporting frame is used, it should be designed to offer a minimum disturbance, and should be located several feet downstream from the meters.

By Pitot Tube.

9(c). When the Pitot tube method is used, the Pitot tube shall be located in a straight run of penstock or conduit, at a distance equal to at least ten pipe diameters from any upstream

By Pitot Tube. (Cont'd)

bend and at least five diameters from a downstream bend. When the observation is made in a circular pipe or penstock, at least two Pitot tubes shall be arranged to traverse two relatively perpendicular diameters, but in the case of very large penstocks or those having symmetrical flow, Pitot tubes shall be arranged to traverse completely or partially the intermediate diameters, giving traverses at forty-five degree intervals.

In determining the velocity in the penstock by the Pitot tubes the static pressure over the cross section shall be measured by from four to eight carefully constructed piezometers, equally spaced around the wall of the penstock at a section one foot in advance of the Pitot tube section to avoid the effect of the Pitot tube supporting structure, the penstock being of uniform cross-section between the piezometers and the points of the Pitot tubes. All piezometers shall be connected to separate gages. The conditions of measurement, including velocity distribution, length of straight run of penstock, and condition of piezometer orifices shall be such that no piezometer shall vary in its readings by more than 10 per cent. of the velocity head from the average of all the piezometers. The piezometer orifices shall be flush with the inside surface of the penstock wall, the passages shall be normal to the wall, and the wall shall be smooth and parallel with the flow in the vicinity of the orifices. The orifices shall be ⅛ inch in diameter.

The velocity at each point in the penstock shall be computed by the formula $V = \sqrt{2gh}$; in which "h" represents the difference in feet between the total dynamic pressure recorded by the Pitot tube at that point and the average static pressure recorded by the piezometers. The velocities so determined shall be plotted as ordinates against values of the areas of the sections of the penstock corresponding to the points of measurement as abscissas, a smooth curve being drawn through the points obtained. The mean velocity in the penstock will then be taken as the mean ordinate of the above curve multiplied by 0.976. This coefficient is based on the average of various comparative tests, and is required to correct for oblique or sinuous flow under the usual conditions in straight penstocks.

When the length of straight run of penstock is insufficient, or when the flow is disturbed by a severe bend or obstruction upstream from the tube or when the average velocity is less than 5

By Pitot Tube. (Cont'd)

feet per second, the above coefficient will not apply correctly, the correct value being considerably lower in such cases, which do not therefore come within the scope of this code. The coefficient corresponds to a tube, the point of which is 3/8 inch in diameter with a 1/8-inch hole, the face being normal to the axis, and at least 3 inches from the nearest surface of the supporting pipe.

By the Screen or Diaphragm Method.

9(b). When the screen method is used a sufficient length of straight flume of uniform cross-section shall be constructed with a close fitting screen filling the cross-section. Provision shall be made for accurately observing the velocity of the screen preferably by electric contacts and chronograph. The length of run of the screen shall be sufficiently in excess of the portion used for measurement to provide ample space for starting and stopping the screen, so as to insure uniform conditions over the measured portion of the run. In determining the discharge the velocity of the screen shall be multiplied by an area intermediate between the net immersed area of the moving screen and the average area of stream cross-section of the portion of the channel traversed. The variation of the level in the flume shall be observed during the course of the run and the average elevation shall be used in determining the area.

By Titration or Chemical Method.

9(c). When the chemical method is used in measuring discharge, care shall be taken to insure that at the point of introducing the dosing solution no portion of the solution shall be carried off by back currents and shall therefore fail to pass to the sampling station, and that the sampling station shall be so placed that no pollution shall be caused by reverse currents, causing fresh water to pass the station from down stream. When necessary, owing to a short length of mixing passage or lack of sufficient disturbance to cause thorough mixing, the dosing pipes shall be so placed that an equal degree of concentration over the entire section of the sampling station shall be obtained. Samples shall be taken from points distributed over the entire sampling section. All necessary precautions shall be observed in taking samples and in observing the end-point of the reaction during titration.

In short tests, care shall be taken to preserve a uniform rate of introduction of the dosing solution. Preliminary observations shall be made to determine the time required after the dosing is started

By Titration or Chemical Method. (Cont'd)

for uniform conditions to become established at the sampling station; and in the actual tests the dosing shall be continued for double this time before sampling is begun. Uniformity of dilution of samples both with respect to location in the section and time of taking shall be considered essential for an acceptable test.

Power Tests of Turbine Supplemented by Efficiency Tests of a Model.

10. When the conditions of an installation are such as to involve serious difficulty or expense in the application of any of the above methods of water measurement, the tests of the installed turbine may be made when acceptable to both parties without measuring the quantity of water, a homologous model of the turbine being constructed and tested at the expense of the Purchaser, and the power delivered by the installed turbine compared with that computed from the model tests.

This method must not be confused with the practice, which has sometimes been followed, of comparing a turbine with a model having a homologous runner, but dissimilar with respect to setting, draft tube or other parts. The runner, guide vanes, draft tube, casing or other adjacent water passages should be geometrically similar in the turbine and model; and when so constructed, the power stepped up from the model tests for the hydraulic equivalent of the speed gives a reliable basis of comparison with the power actually obtained from the installed unit.

The power of the model when operating at the hydraulic equivalent of the speed of the large unit in the tests of the latter, at the same proportional gate opening, is to be multiplied by the ratio of the area of the discharge orifices of the large turbine runner to that of the model, and by the three-halves power of the ratio of the head existing in the tests of the large unit to the head in the model tests. When the power so computed agrees exactly with that obtained from the installed unit, the efficiency of the large unit shall be considered to be identical with that of the model; and when the power of the large unit exceeds that thus computed from the model, the efficiency of the large unit shall be considered to be in excess of that of the model. In measuring the gate opening the actual opening of the gates shall be determined, and care shall be taken to avoid errors due to the effect of the pressure on the vanes.

Appendix.

Special Methods of Water Measurement.

11. The following methods of water measurement may sometimes be applied; these are, however, subject to limitations, and are available only under special conditions. They have not as a rule been in sufficiently general use in turbine testing to permit full reliance to be placed on them until opportunities are afforded for checking them against the methods already given.

By the Bulk or Volumetric Method.

11(a). Water measurement by weight or volume is not usually available; the former is limited to laboratory use, which is outside the scope of this code. The bulk method is applicable only when there is available a reservoir of regular form, the volume of which up to various water levels may be accurately measured, and when the following conditions may be observed.

The draw-down or filling of the reservoir must not cause a variation in head on the turbine during a run exceeding the limits specified under Section 4(b), namely, a total of 4 per cent. of the head. It must be possible to shut off completely all inflow into or outflow from the reservoir. The tightness of the gates and reservoir walls must be tested by closing all gates, and observing over a time of several hours the rate of rise or fall of water level in the reservoir throughout the full range of variation of level which will be used in the turbine test. At the same time any leakage through the turbine head gates is to be measured. The surface elevation in the reservoir is not to be so affected by velocity or wind effects as to cause local variations in level of more than 5 per cent. of the total draw-down used in the turbine tests. This variation is to be observed by gages distributed over the whole reservoir which are to be read simultaneously at short intervals throughout the test. The effect of surface evaporation shall be investigated and corrections applied to cover it when local conditions are such that it becomes appreciable.

By Venturi Meter.

11(b). When it is possible to install a Venturi meter not exceeding in dimensions or differing in conditions from meters whose coefficiencies have previously been determined in accurate tests, the Venturi meter may be used. The meter shall be similar in proportion to meters previously tested.

By Color Velocity Method.

11(c). When the water used by the turbine passes through a conduit suited to the purpose, the color method of quantity determination may be used, depending upon the time of passage between two points of a mass of color injected into the stream. The distance between the two points where the passage of the color is observed must be sufficiently great to render the interval between the times of passage of color at the two stations large compared to the time required for all the color to pass either station. The conduit must be of sufficiently regular form to permit its cross-sectional areas to be accurately measured at all points between the stations.

By Brine Velocity Method.

11(d). A method similar to 11 (c) adapted to closed conduits has been used, consisting in the injection of a mass of brine, the time of passage of which is detected by the variation in electrical resistance between two contacts placed in the stream. A pair of such contacts is placed at each station, and the time of passage of the brime between the stations is chronographically recorded by a specially arranged wattmeter. The stations should be arranged as under 11(c).

By Color Density Method.

11(e). The coloration or color density method may also be employed for approximate tests, this method depending on the use of a colored dosing solution in place of a salt solution in a manner similar to the chemical method of 9(e), observation of the color density replacing the titration.

By Resistance of Salt Solution.

11(f). A method which has been used experimentally is similar to the chemical method of 9(e), except that the amount of chemical (salt) in solution is determined by measurement of the electrical resistance of the solution instead of by titration. Care is required to guard against changes in resistance due to small temperature variations.

Measurement of Water Horsepower in Plants Containing a Fall Increaser.

12. In case of an installation including a fall increaser or other device utilizing an auxiliary flow for increasing the effective head, the following provisions shall be observed: In determining the efficiency of the turbine proper, considered separately from the fall increaser, the fall increaser shall be closed, and precautions shall be taken that no water except that passing through

Measurement of Water Horsepower in Plants Containing a Fall Increaser. (Cont'd)

the turbine shall enter the system between the points at which the head is measured.

In order to determine the performance of the combined hydraulic installation, including both turbine and fall increaser, the total water horsepower shall be computed from the sum of the turbine discharge multiplied by the head on the turbine, and the auxiliary discharge multiplied by the head on the fall increaser. The head on the turbine shall be measured from a point immediately in advance of the point of intake to the turbine proper, as above provided, and the head on the fall increaser shall be measured from a point immediately in advance of the intake gates of the increaser, the head in each case being measured to a point below the junction of the two streams at the outflow from the plant. For the computation of water horsepower it will be necessary to determine the division of the total discharge between the turbine and fall increaser. This may be done when practicable by separately measuring the water admitted to the turbine during the operation of the fall increaser.

If, owing to the arrangement of the fall increaser, it is impracticable to separate the water horsepower of the turbine from that of the fall increaser, the gross efficiency of the combined installation may be determined by measuring the combined total flow, and the total head from a point common to the two flows before entering the plant to a point after they are reunited below the final point of discharge.